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TECHNICAL REPORT
70-2-CE

THE WEAR RESISTANCE OF COTTON TEXTILES

by

Louis I. Weiner
Chief
Fiber and Fabric Research and Engineering Branch
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Project Reference:
1T062105A329

Series: TS-163

July 1969

Clothing and Personal Life Support Equipment Laboratory
U.S. ARMY NATICK LABORATORIES
Natick, Massachusetts 01760

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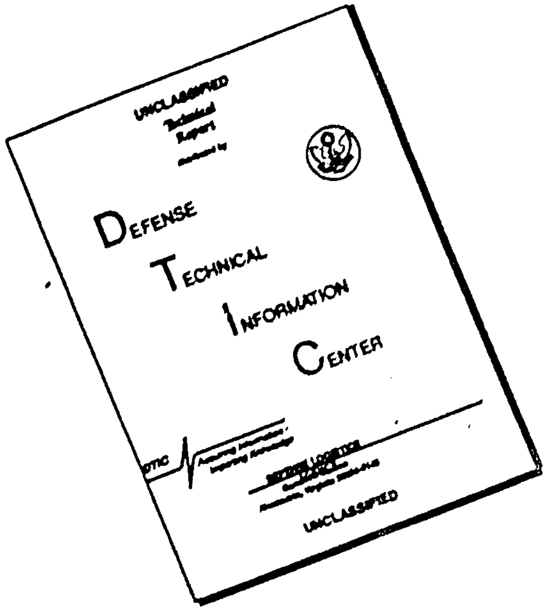

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FOREWORD

The U.S. Army Natick Laboratories have been interested in problems on wear resistance since the beginning of World War II, when studies were initiated to extend the service life of military clothing. These studies led to reductions in the need for logistic support in the field and resulted in significant monetary savings.

With the introduction of the many new man-made fibers and blends, and the increasing use of resin treatments for functional fabrics, it became evident that much of the information obtained on the basic cotton and wool fabrics was no longer applicable and that additional analyses would be required to arrive at a basis for optimizing the serviceability of the new materials and finishes.

In 1963, a report was published (Textile Series Report No. 125 - Wear Resistance of Military Textiles) which summarized work on the development of wear tests and scoring methods, and dealt with some new concepts on wear mechanisms and field testing, particularly as they applied to man-made fibers and blends.

The present report is a summary of the more recent United States Army Natick Laboratories' work on wear. Included are: findings on the application of the theories of metal wear to textile fabrics; a description of two abrasion testers which produce a type of wear closely related to that noted in the field wear of combat clothing; the results of correlation studies of laboratory abrasion instruments with accelerated wear course and field wear; and some interesting observations on the directional wear of fabrics in laundering which have particular value for garments made of durable-press or other resin-treated fabrics.

Acknowledged are the contributions of personnel in the Clothing and Personal Life Support Equipment Laboratory of the United States Army Natick Laboratories, including Clarence J. Pope, Barbara L. Hodam, Elliott A. Snell, and Harry F. Smith. The work was performed under Project 1T062105A329, Organic Materials Research for Army Materiel.

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ABSTRACT

Investigations on the wear of cotton fabrics were conducted by the U.S. Army Natick Laboratories. It was found that the theories of "adhesive" and "abrasive" wear, originally developed for metals, when applied to textile wear problems, provide new insights into the interpretation of laboratory and field measures of wear resistance. The predominant form of wear of military clothing is of the "abrasive" type. This finding stimulated the development of two instruments: the Smith Sand-Abrader and the Sand-Blast Tester, which provide essentially the abrasive type of wear. These two instruments are described. Correlation studies indicate that the Sand-Abrader and the Sand-Blast Tester predict accelerated wear-course wear and simulated combat-wear with a reasonable degree of precision.

Early studies made by the Army on the influence of garment fabric weave and weave orientation both in field and laboratory wear were extended to determine their influence on the wear that occurs in laundering. With the increased use of resin treatments to produce desired functional properties in military fabrics, this type of wear has become more important because of the sensitivity of resin-treated fabrics to laundering damage. It was found that the location and rate of edge wear in seams is a function of weave type and fabric orientation. In poplins, failure occurs predominantly in those warp yarns bent around the seam edge which is perpendicular to the warp direction of the fabric. In sateens, made up with the filling-flush side of the fabric to the outside of the seam, failure occurs predominantly in the filling yarns at the seam edge parallel to the filling direction of the cloth. The magnitude of the differences observed are such as to suggest means of significantly reducing edge wear in military garments by correct positioning of the fabric in seam structures.

THE WEAR RESISTANCE OF COTTON TEXTILES

1. Introduction

When one considers ways and means of improving the wear resistance of cotton fabrics, there is a tendency to conclude that only the inclusion of a high work-to-rupture fiber such as nylon or polyester is the answer. That this is not the case is illustrated by the experience of the U.S. Army Natick Laboratories (NLABS) where significant strides have been made in improving the wear of cotton fabrics through the recognition of the mechanism by which wear occurs and by taking advantage of some interesting peculiarities in the wear of certain weave constructions.

The design of fabrics of improved wear resistance has been greatly aided by the development of two new testers which predict field wear within reasonable limits of error. The development of these testers has been a direct outgrowth of a better understanding of textile wear mechanisms, derived, in part, from an extrapolation of findings on metal wear. In addition, the extension of some early work on wear as related to fabric weave has led to some significant observations on wear in laundering.

2. Theories of Wear

It has been difficult to develop a consistent theory of textile wear because of the complex interactions of the elements of fabric structure with the abradant system. Three actions have been cited [1] which govern the mechanical breakdown of textiles during abrasion: frictional wear, cutting, and plucking or snagging of fibers. An examination of these three actions, from the standpoint of the factors which influence the extent to which they operate, leads to the conclusion that, for a given abradant and abrading system, the rate and extent of abrasion will be determined by: (1) the nature of the interface between the fibers and the abradant, (2) the external loading conditions, and (3) the energy-absorbing ability or a factor related to energy-absorbing ability of the fiber components.

The interface can involve either a low friction or a high friction system. In a low friction system, the surfaces will slide smoothly over one another and there will be little opportunity for significant attraction between abradant and fiber molecules. Thus, the role of lubrication is important in some types of textile abrasion. It is surprising that so little attention has been paid to the role of lubrication in the wear of textiles, since in the wear of metals, lubrication always has been a major consideration. Much of the textile work in the past has assumed that fabrics received from a mill either are free from lubricants or can have any residual lubricating agent removed by one or more launderings and rinsings. That this is not relevant can be demonstrated by extracting fabric with chloroform in a Soxhlet apparatus and noting the marked decrease in level of abrasion resistance.

STOLL FLEX ABRASION

ORIGINAL SAMPLE	4200 cycles
CHLOROFORM EXTRACTED	660 cycles
EXTRACT REAPPLIED	3920 cycles

The flex blade of the U.S. Stoll[2] or of the British BFT[3] abrader may be used to show this effect.

Since these lubricant-associated differences are not noted to the same degree on other types of abrasion testers, such as the Wyzenbeek[4] and Taber[4], it is interesting to speculate on the wear mechanisms which account for the response or lack of response to the presence of lubricating agents. The concepts of "adhesive" and "abrasive" wear, as used for metals, form a logical basis for classifying textile wear also.

During adhesive wear[5, 6] junctions are formed between the metal and the abradant which are small in number but great in strength. As one surface moves with respect to the other, these junctions are sheared. If the shearing takes place within the junction rather than at the interface, a wear particle is formed. The volume of material sheared per unit length of abraded surface is formulated as:[6]

$$V = K_m \left(\frac{f - f_1}{f_m - f_1} \right)^{3/2} \frac{L}{3p}$$

where K_m = the probability that a wear particle will form

f = coefficient of friction at the interface

f_m = coefficient of friction - no lubrication

f_1 = coefficient of friction - perfect lubrication

L = load

p = penetration hardness

Thus, in adhesive wear, friction, as determined by the presence or absence of lubricants, will have a significant influence on the rate of wear.

In abrasive wear, on the other hand, abradant particles actually dig into and gouge out matter from beneath the surface of the material being abraded. In this type of wear, the presence of a lubricant on the surface has little or no influence on the rate of abrasion. With the exception of the friction quotient, the equation[7] for abrasive wear is similar to that for adhesive wear. The volume of worn material per unit length is equal to a proportionality factor multiplied by the load and divided by the penetration hardness, thus:

$$V = \frac{L (\cot \theta)}{\pi p}$$

where $\cot \theta/\pi$ represents the proportionality factor derived from the assumed shape of the abradant particle. Weiner and Pope[8] classified the common laboratory textile abrasion machines on the basis of "adhesive" and "abrasive" wear.

3. Load

It is not possible to apply the L/p ratio to textiles in the same sense that it is applied in the equations for metals. A significant amount of work[9, 10, 11] indicates that the rate of wear of textiles varies as the applied load. The general relationship cited is $C = KP^{-k}$, where C is cycles, P is the load per unit area, and K and k are constants. Susich[11], on the other hand, working with yarns on the flex element of the Stoll Abrader, found that the logarithm of number of cycles at break varied linearly with the load on the abrasion head. However, recent work done at the U. S. Army Natick Laboratories on the Taber Abrader confirmed the general power law relationship, and a plot of logarithm of cycles to hole formation versus logarithm of load gave a linear relationship (Figure 1).

4. Energy Considerations

Penetration hardness does not have the same significance for fibers as it does for metals. In the case of abrasive wear of metals, work done at the Massachusetts Institute of Technology[6] suggests that abrasive wear, even for metals, may be independent of "p" in some cases and that "wear resistance is affected by the amount of elastic deformation the softer metal can undergo in attempting to avoid abrasion." For textiles, there are indications that the work-to-rupture of the fiber or some parameter related to work-to-rupture may be a good predictor of wear potential. Hamburger[12] found a linear relationship between a computed energy coefficient and a durability coefficient for several fiber types. Shah[13], working with additional fiber types, failed to verify the original relationship of Hamburger. Backer[9] suggested that the ratio of the square of the shear tenacity to initial Young's modulus was a good predictor of wear resistance. Dimensionally, this ratio is analogous to work-to-rupture. Several relationships, based on energy-absorbing ability or work functions, have been published.[14]

It is tempting to use weighting or adjusting factors to improve correlations of physical and mechanical properties with wear. While these provide satisfaction to the laboratory worker, attempts to apply these relationships to other test

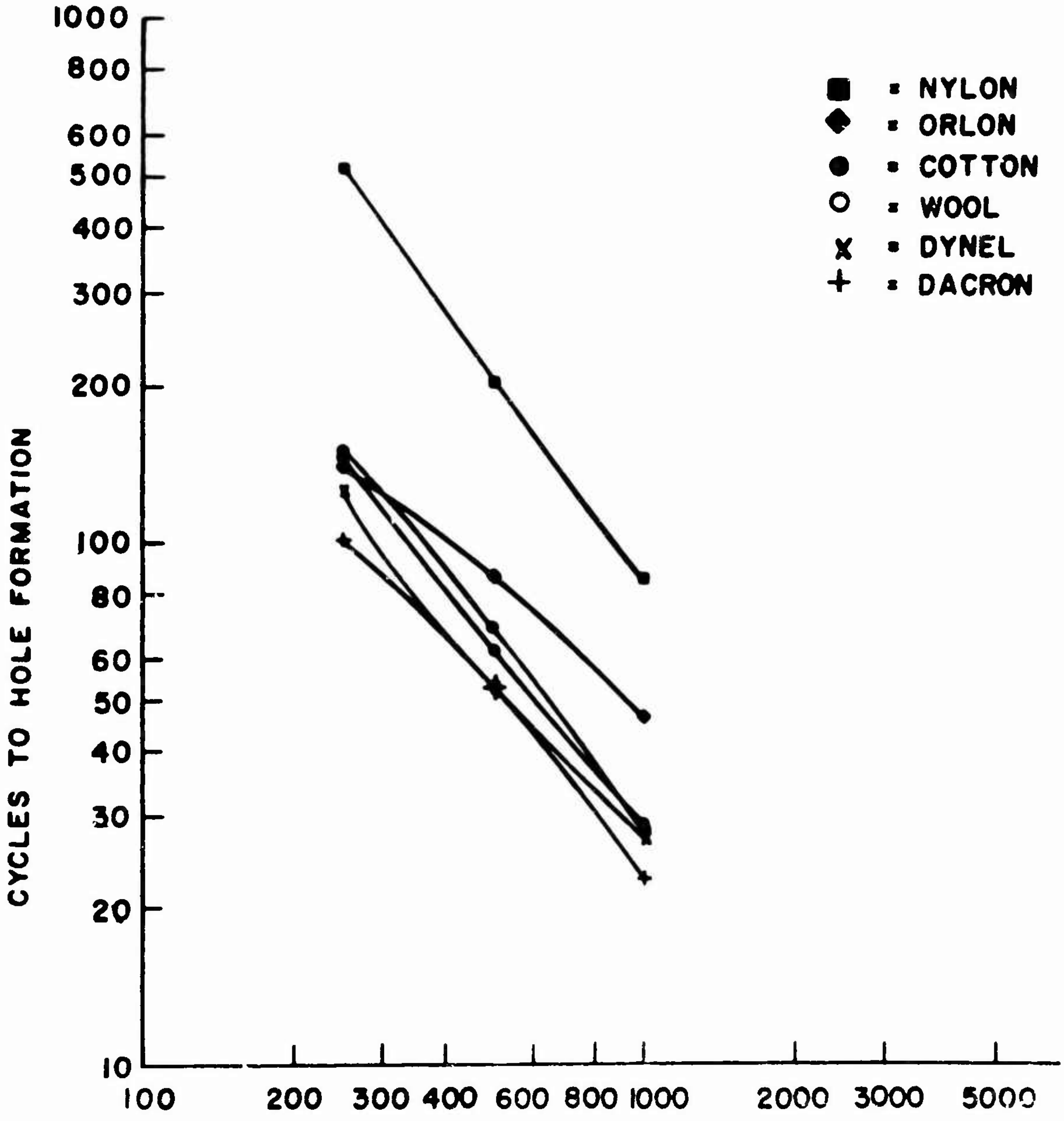


FIGURE 1. RELATIONSHIP BETWEEN CYCLES AND APPLIED LOAD

situations and materials quite often lead to disappointment. In one recent trial, Hodam (15), using plain weave fabrics, developed a relationship involving the ratio of the work-to-rupture of the component fibers to the load on the fabric, adjusted by the weight of the fabric, the sum of the warp and filling textures, and the area of abrasion under the wheels of the Taber Abrader. Interestingly, the results of these calculations gave numerical values which matched quite closely the number of "CYCLES x 10"*, observed at three different loading levels, for the six fabrics. Graphs for different fiber types (Figures 2 and 3) show a comparison of the calculated to the experimental values. The solid line in each graph represents identical values for calculated and experimental data.

5. Sand and Sand-Blast Abraders

A major benefit derived from the study of "adhesive" and "abrasive" wear, and of the factors that contribute to these types of wear, is the classification of laboratory testers and field wear systems by type. Predictions of field wear from laboratory abrasion data can now be made with more confidence than in the past.

Analysis of the results of a large series of field wear trials made on a simulated combat wear course at Ft. Lee, Virginia, and in basic training exercises at Ft. Jackson, South Carolina, revealed that the predominant form of wear in military garments is of the "abrasive" type. It is probable that "abrasive" wear is a significant form of wear in many civilian types of garments such as children's clothing, work clothes, sports clothes, and the like. As a result of this observation, attention was given to the development of two instruments - The Smith Sand Abrader (16) and the Sand-Blast Tester (17), which produce the abrasive type of wear by means of the action of sand.

In the Smith Sand Abrader (Figure 4), a stream of sand is allowed to impinge at a constant rate upon a standard cement block which is supported horizontally in the trough of the instrument. A clamp, holding the fabric under test, oscillates back and forth over the sand-block combination. The end-point

*Factor of 10 used to convert Taber "Calibrade" to Taber "Calibrase" values

FIGURE 2. COMPARISON OF ACTUAL AND CALCULATED ABRASION CYCLES TO HOLE FORMATION

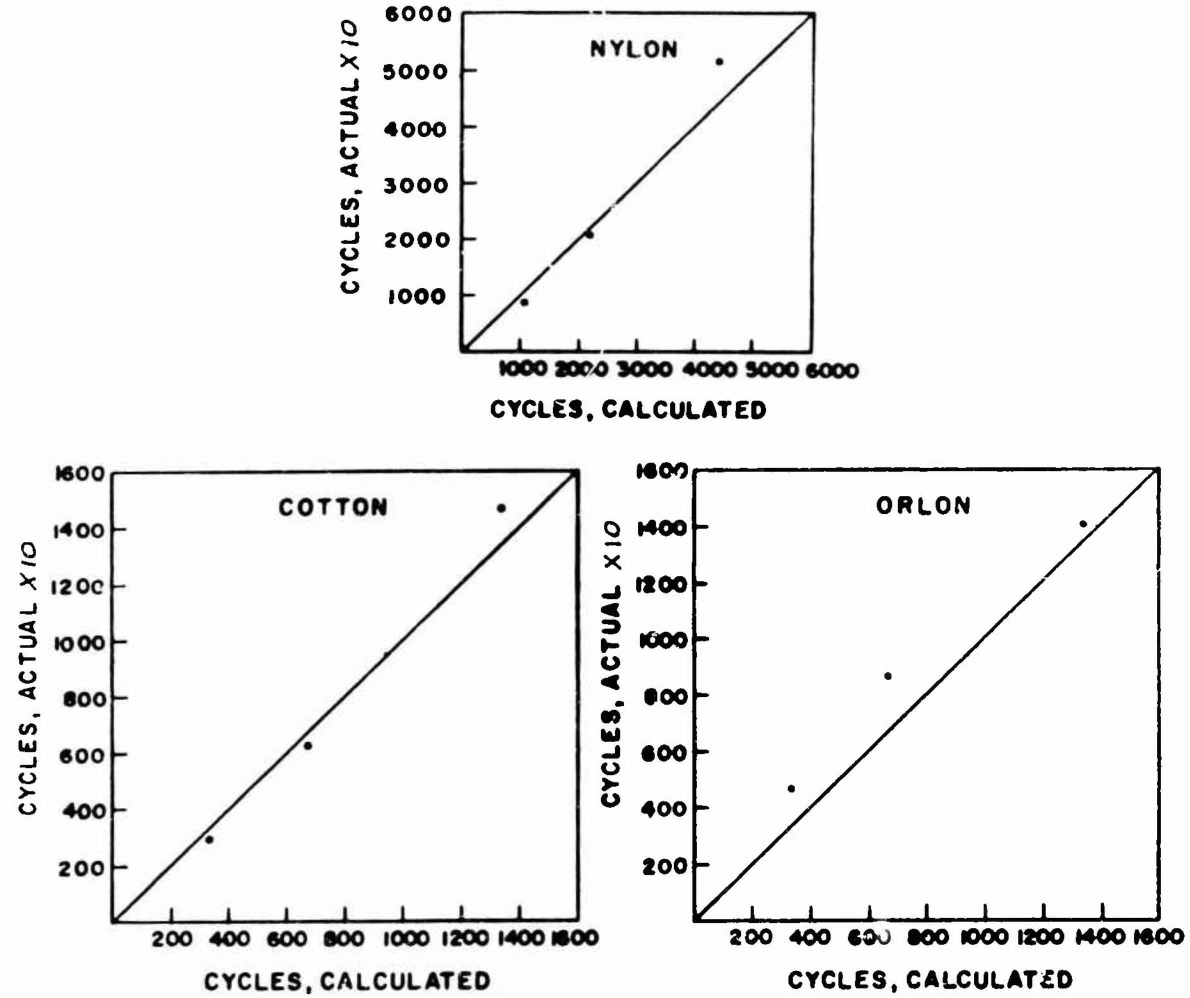
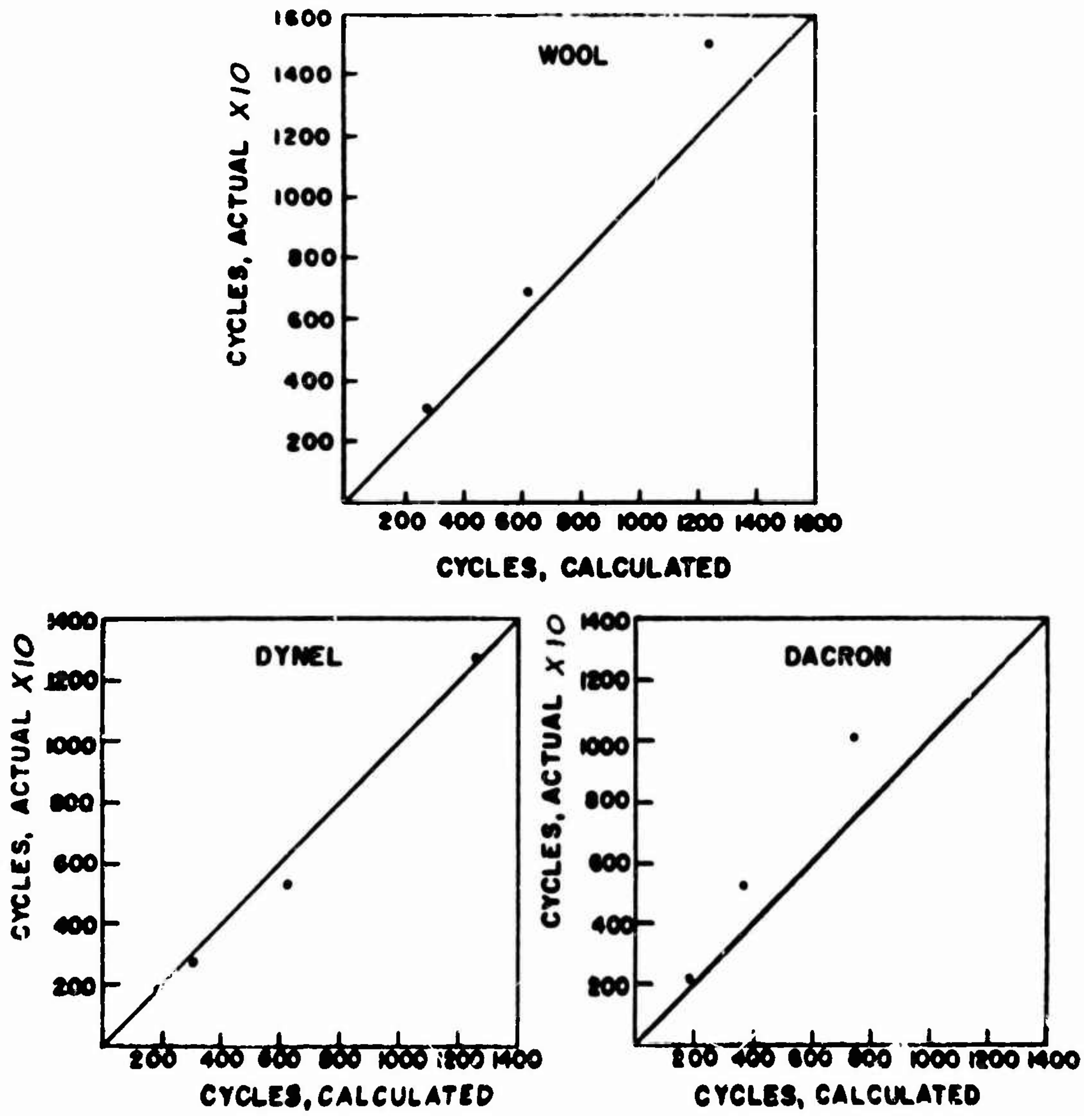
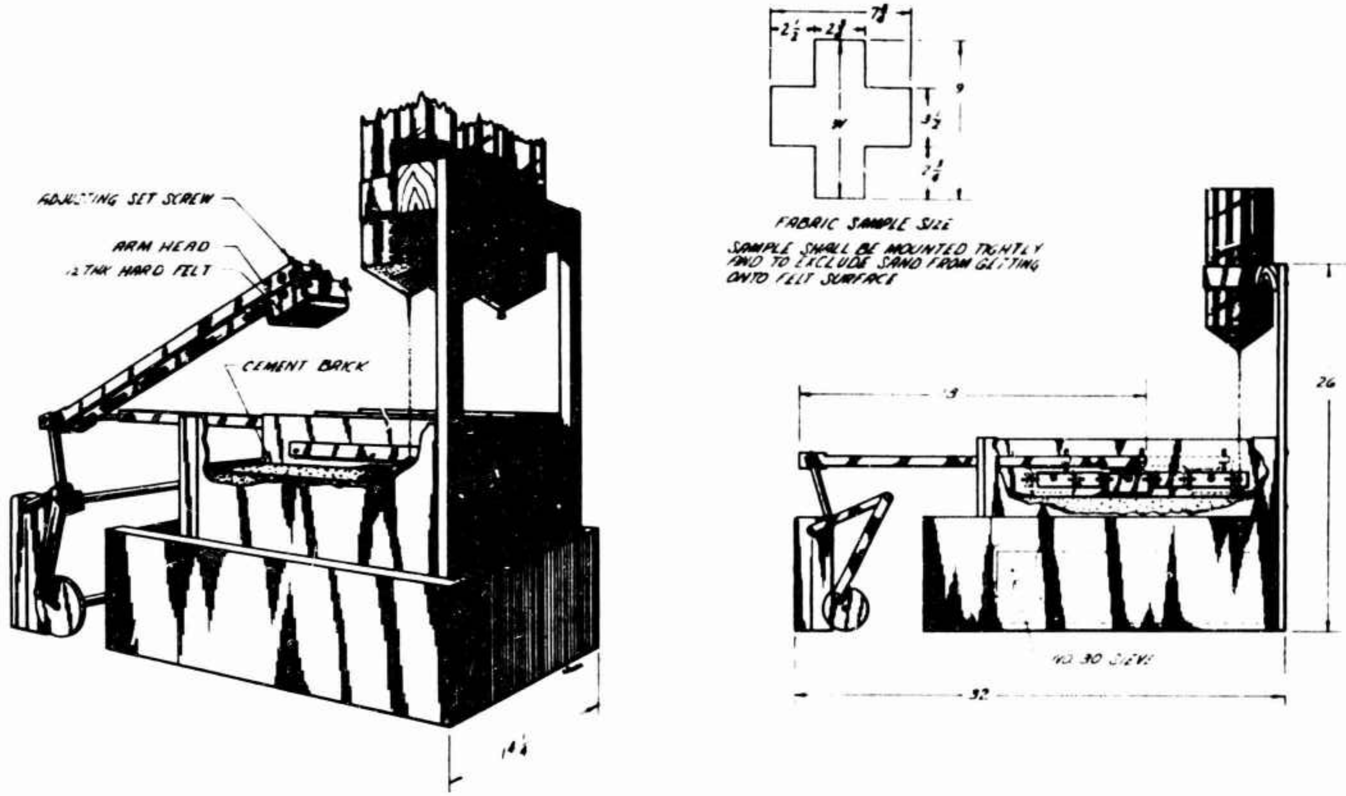


FIGURE 3 COMPARISON OF ACTUAL AND CALCULATED ABRASION CYCLES TO HOLE FORMATION





SMITH SAND ABRADER

NOTES
1 ARM HEAD TO BE 2 x 3 IN SIZE, TO WEIGH 1/2 LB PER SQ INCH, TOTAL OF 3 LBS
2 ARM HEAD TO TILT 5° MAX WITH USE OF ADJUSTING SET SCREWS
3 80 ± 20 STROKES PER MINUTE, STROKE LGTH OF 9 INCHES
4 ARM HEAD AND SIDE OF STALL TO HAVE 1/10 INCH CLEARANCE TO PREVENT SIDE MOVEMENT
5 SAND USED SHALL PASS THRU NO. 16 (1190 MICRONS), BUT NOT THRU NO. 30 (590 MICRONS) U.S STANDARD SIEVE.
6 SAND FLOW SHALL BE EXTREMELY SLOW

Figure 4. Smith Sand Abrader

is subjective and is determined either as the number of cycles required to form a hole of a given size or from a comparative assessment of wear evaluated visually after a fixed number of cycles. The former procedure is used more conventionally.

The Sand-Blast Tester (Figure 5) has as its basic component a spark-plug cleaner which has been modified with a special fabric-holding clamp and a pressure-recording device to indicate the end-point. During the operation of the Sand-Blast tester, a stream of sand is directed against the underside of the fabric at predetermined blast pressure until a hole forms in the fabric. Hole formation is denoted by an instantaneous increase in the pressure-recording device. The Sand-Blast tester has a number of advantages, the most favorable of which are low cost, rapidity of testing, and the small size of the sample required. The holes in the samples formed at the end-point are uniform in size and make comparisons among different fabrics quite valid. The wear in both of these instruments is independent of the presence or absence of lubricants and, thus, is of the "abrasive" type.

6. Relationship of Laboratory Tests to Field Wear

The need has long been recognized for validating laboratory abrasion testing against actual wear in the field. The U.S. Army Natick Laboratories conducted several studies to shed light on this problem. In an early study[1] conducted in 1948, garments made from a broad range of fabric types were worn on an accelerated wear course, and the same fabrics were tested in the laboratory on the Stoll-Flex Abrader.

With the development of the Sand Abrader and the Sand-Blast Tester, additional correlation studies were made which involved both the accelerated wear course at Ft. Lee, Virginia and field wear for several overgarment materials and uniform fabrics. The accelerated wear course* (Figure 6) consists of a series of obstacles, such as sand pits, logs, railroad embankments, concrete culverts, and board-floors, over which the individuals wearing the test items crawl in a controlled manner in accordance with a fixed-rate schedule. After every two traversals over the course, the garments are laundered and a wear score (Table I) is computed from the size and number of holes, tears, frays, and worn areas.

*Originally designated as the Quartermaster Board Combat Course.

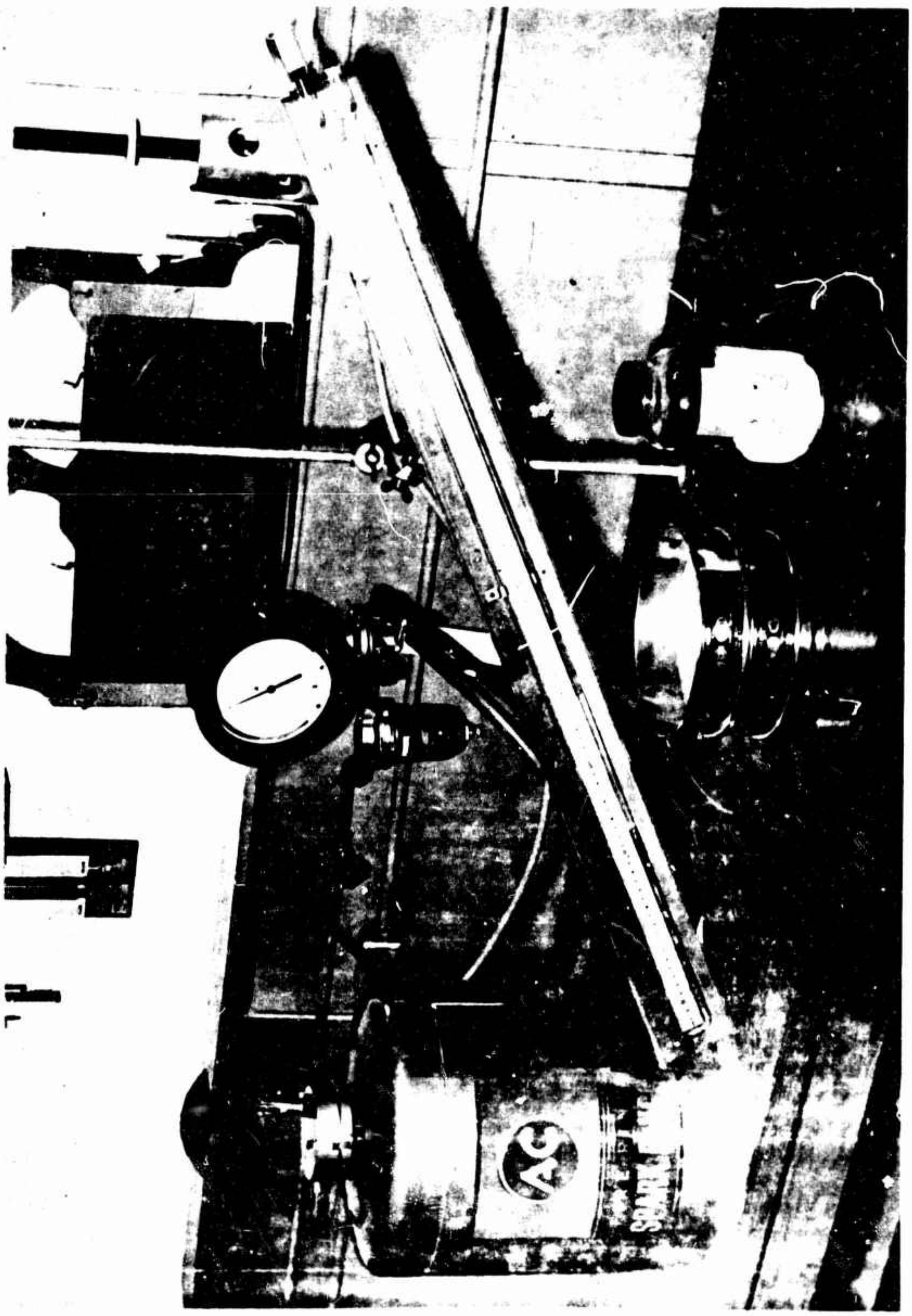


Figure 5. Sand-Blast Tester

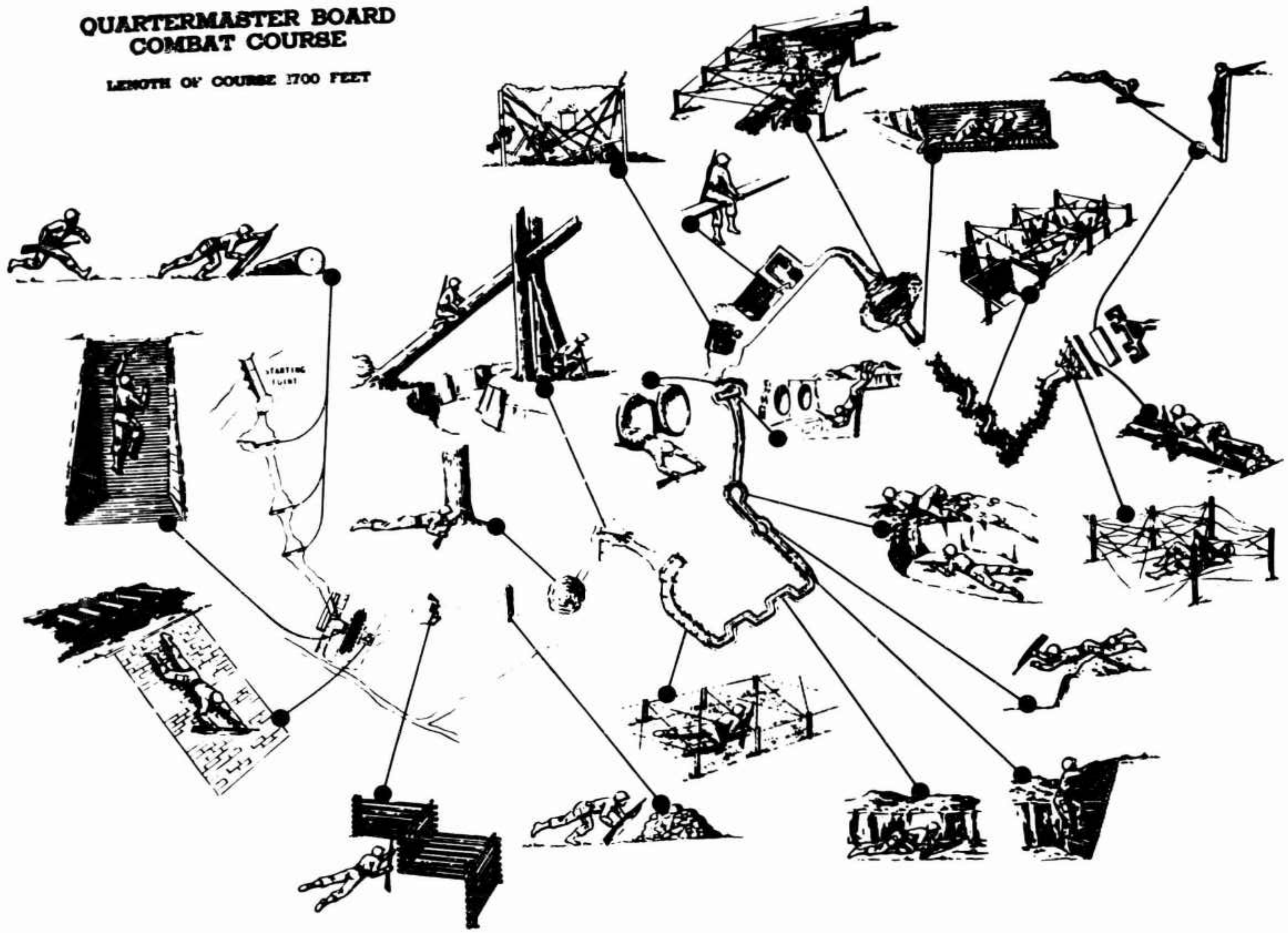


Figure 6. Quartermaster Board Combat Course

TABLE I

SCORING SYSTEM USED IN WEAR-COURSE TESTING

Type of Failure	Degree 1	2	3	4	5	6
			Definition of Degree			
Holes (diameter-inches)	$\leqq 0{\cdot}25$	$> 0{\cdot}25 \leqq 0{\cdot}5$	$> 0{\cdot}5 \leqq 1{\cdot}0$	$> 1{\cdot}0 \leqq 1{\cdot}5$	$> 1{\cdot}5 \leqq 2{\cdot}0$	$> 2{\cdot}0$
Tears in wear area* (length-inches)	$\leqq 1{\cdot}0$	$> 1{\cdot}0 \leqq 2{\cdot}0$	$> 2{\cdot}0 \leqq 3{\cdot}0$	$> 3{\cdot}0 \leqq 5{\cdot}0$	$> 5{\cdot}0 \leqq 7{\cdot}0$	$> 7{\cdot}0$
Frays (length-inches)	$\leqq 1{\cdot}0$	$> 1{\cdot}0 \leqq 3{\cdot}0$	$> 3{\cdot}0 \leqq 6{\cdot}0$	$> 6{\cdot}0 \leqq 10{\cdot}0$	$> 10{\cdot}0 \leqq 15{\cdot}0$	$> 15{\cdot}0$
Wear areas (sq.inches)	$\leqq 4{\cdot}0$	$> 4{\cdot}0 \leqq 9{\cdot}0$	$> 9{\cdot}0 \leqq 16{\cdot}0$	$> 16{\cdot}0 \leqq 25{\cdot}0$	$> 25{\cdot}0 \leqq 36{\cdot}0$	$> 36{\cdot}0$
			Points Scored			
Holes	5	9	11	13	14	15
Tears in wear area* ...	5	9	11	13	14	15
Frays	0·5	1	2	3	4	5
Wear areas	4	6	9	11	13	15

*For purposes of evaluating the serviceability of fabrics as such, instances of accidental tear, stitching failures, bar tacking failures and button failures are recorded, but not scored. After recording they are repaired.

Field wear was accomplished differently for the overgarments and the uniform fabrics. The overgarments were worn by troops in actual field duty that exposed the materials to thorns, underbrush, and rugged terrain. The uniforms were worn by troops engaged in basic training. The overgarments were designed to be inexpensive and expendable (if necessary) and long life was not the major criterion of performance; as a result, their performance was scored in terms of days of wear. The uniform fabrics, on the other hand, were much more durable and their performance was scored as weeks of wear.

The relationship of Sand Abrader and Sand-Blast wear to accelerated wear course wear and days of field wear for the overgarments and weeks of field wear for the uniform fabrics is shown in Figures 7 and 8. Each plotted point represents the performance of one type of fabric. For the eight combinations of data, five of the correlation coefficients are excellent and two are good. In the case of the uniform fabrics, the accelerated wear course failed to distinguish among the three best wearing fabrics, although both types of laboratory abraders and field wear did discriminate. The correlation coefficients computed on the basis of the actual test values are given in Table II. While it is not intended to convey the impression that the correlations obtained pave the way for the unqualified prediction of field wear from laboratory data, it is believed that the Sand Abrader and the Sand-Blast tester provide a reasonable degree of assurance in predicting the relative ranking of fabrics subjected to field wear of the "abrasive" type.

TABLE II

CORRELATION COEFFICIENTS

	SAND ABRADER	SAND BLAST TESTER
Field Wear		
Overgarments	.96	.85
Uniforms	.95	.99
Accelerated Wear		
Overgarments	.99	.95
Uniforms	.82	.54

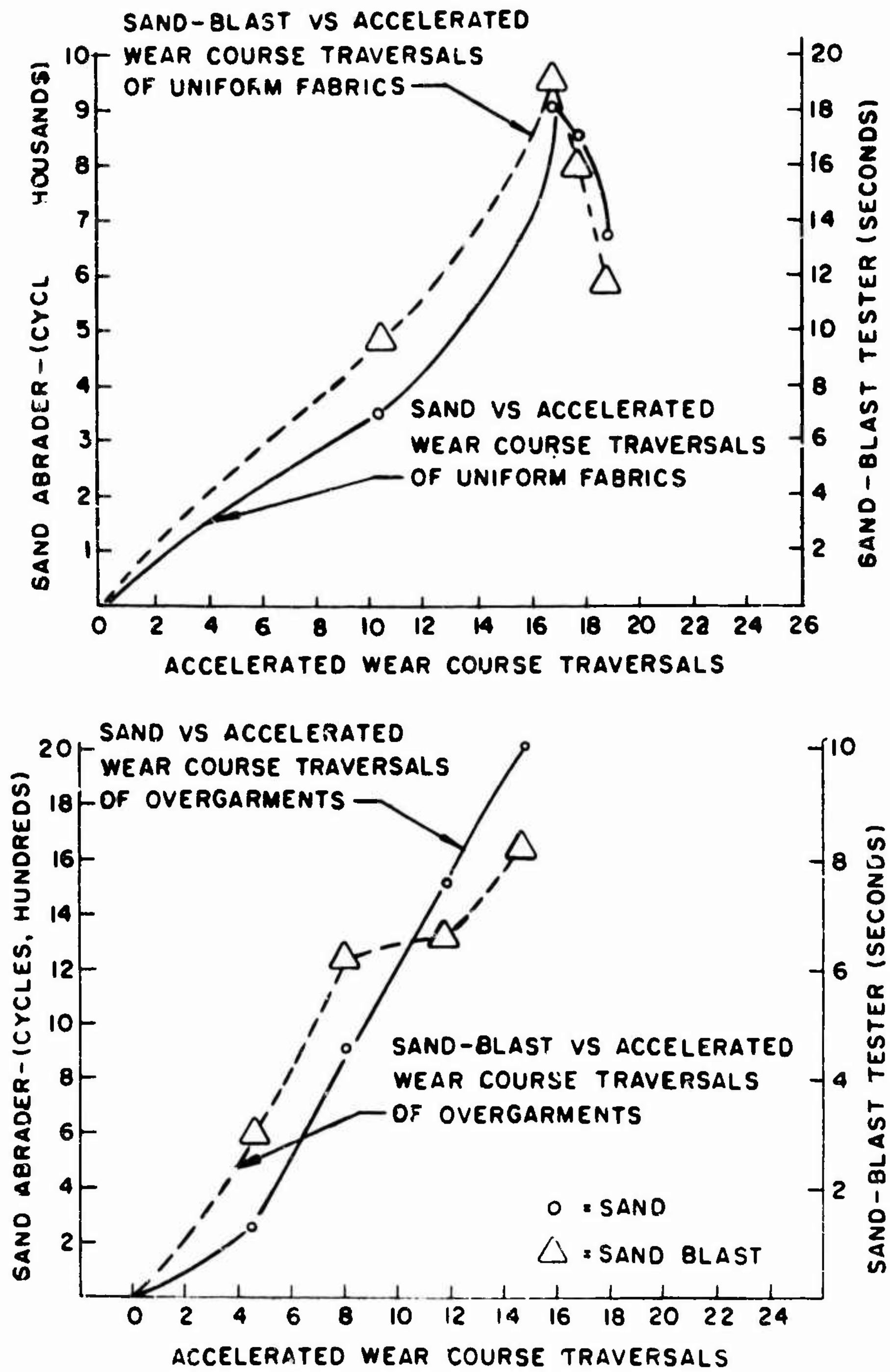


FIG. 7 RELATIONSHIP OF LABORATORY ABRASION TO ACCELERATED WEAR COURSE TRAVERSALS

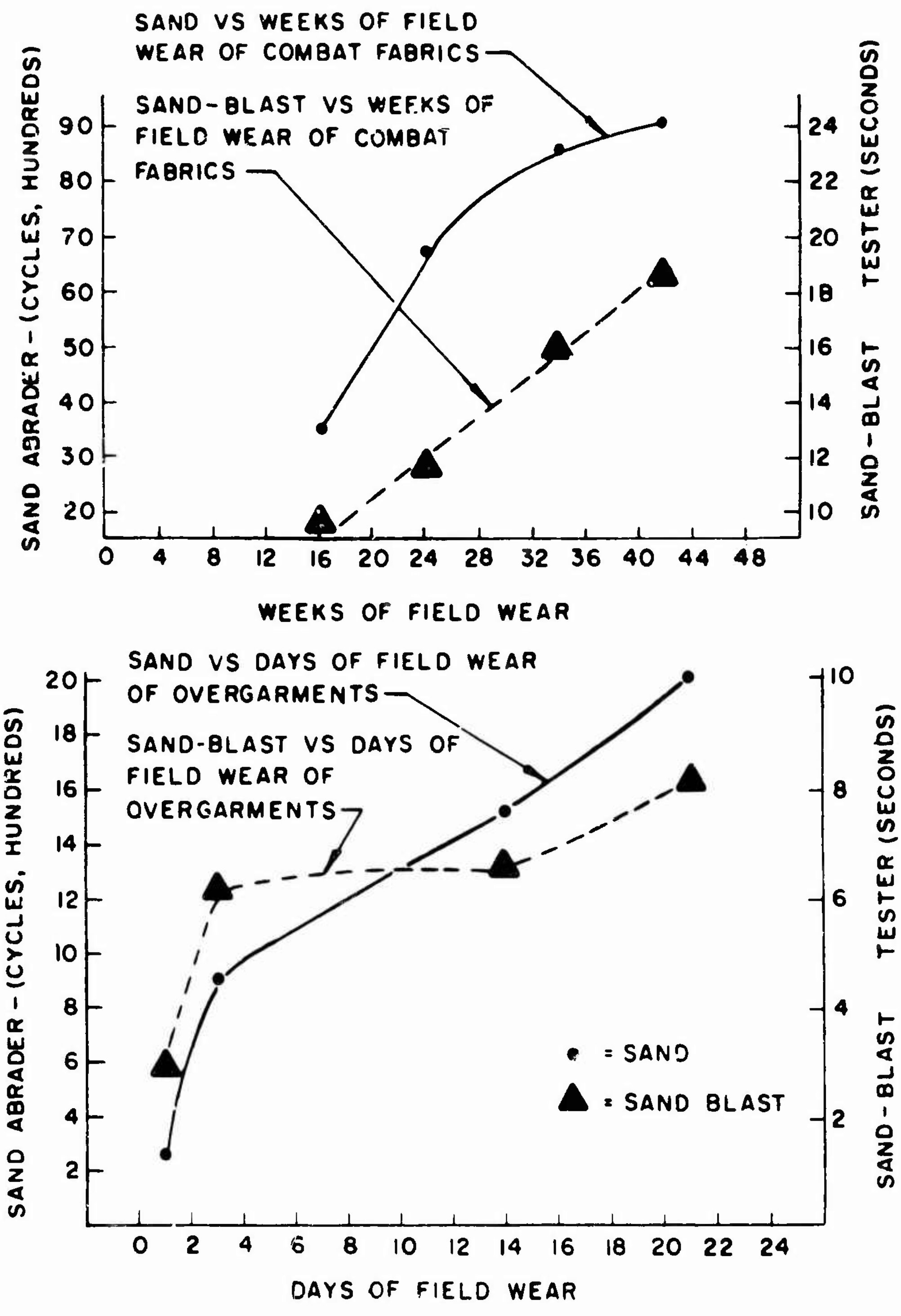


FIG. 8. RELATIONSHIP OF LABORATORY ABRASION TO FIELD WEAR

7. Directional Effects in the Laboratory Wear of Cotton Fabrics

In the make-up of garments, it is conventional to place the fabric so that its "face" is to the outside of the garment. In some constructions, such as the plain weave, face versus back placement makes no difference in level of wear resistance. But in the longer float weaves such as the twills and sateens, a significant increase in wear life may result from optimum utilization of face-to-back wear differences. The classic example of this phenomenon is the 8.5-ounce sateen used by the U.S. military services as a fatigue garment and also for cold-weather combat clothing.

The 8.5-ounce sateen (Figure 9) is of the five-harness variety in which each yarn "floats" over four yarns in the opposing yarn system and then goes under one yarn - this process repeating itself in a "latin-square" interlacing pattern throughout the weave. This interlacing arrangement produces a fabric that is distinctly different from face-to-back. On the face, the yarn system that shows predominantly is the warp, while on the back, the filling yarn system is most prominent. Significant differences in wear resistance will occur depending upon whether the predominantly warp or predominantly filling side of the cloth is fabricated to the outside of the garment. If trousers, for example, are cut from sateen cloth so that the warp yarns run the length of the legs (which is conventional), but the predominantly filling side of the cloth is positioned to the outside of the garment, then higher levels of wear resistance will result. The explanation for this is that the warp yarns, which are the stress-bearing yarns in the trouser system, are protected from abrasive action by the heavy coverage of filling yarns. It becomes necessary for the filling yarns to be almost completely worn through before the abrasive action is applied to the warp yarns. As a result, the warp yarns will maintain their ability to sustain tensile stresses applied to them during normal wear for a much longer period of time. If the predominantly warp side of the cloth is positioned to the outside of the garment (with the warp yarns parallel to the long direction of the trousers), the warp yarns would not be in a protected situation and would start to wear much earlier in the abrasive process and would lose their stress-supporting ability more rapidly.

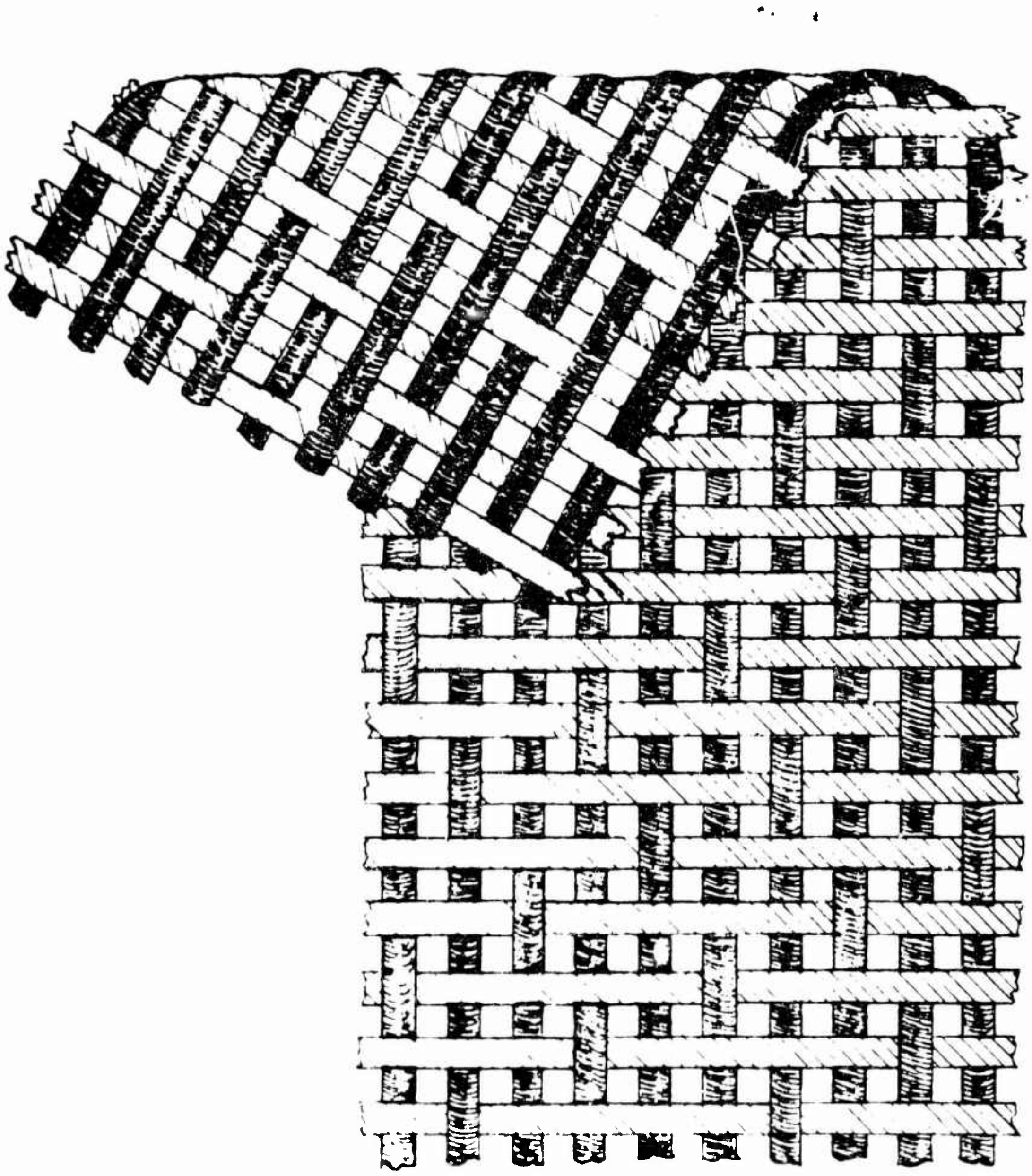


Figure 9. Face and Back Views of Sateen Weave

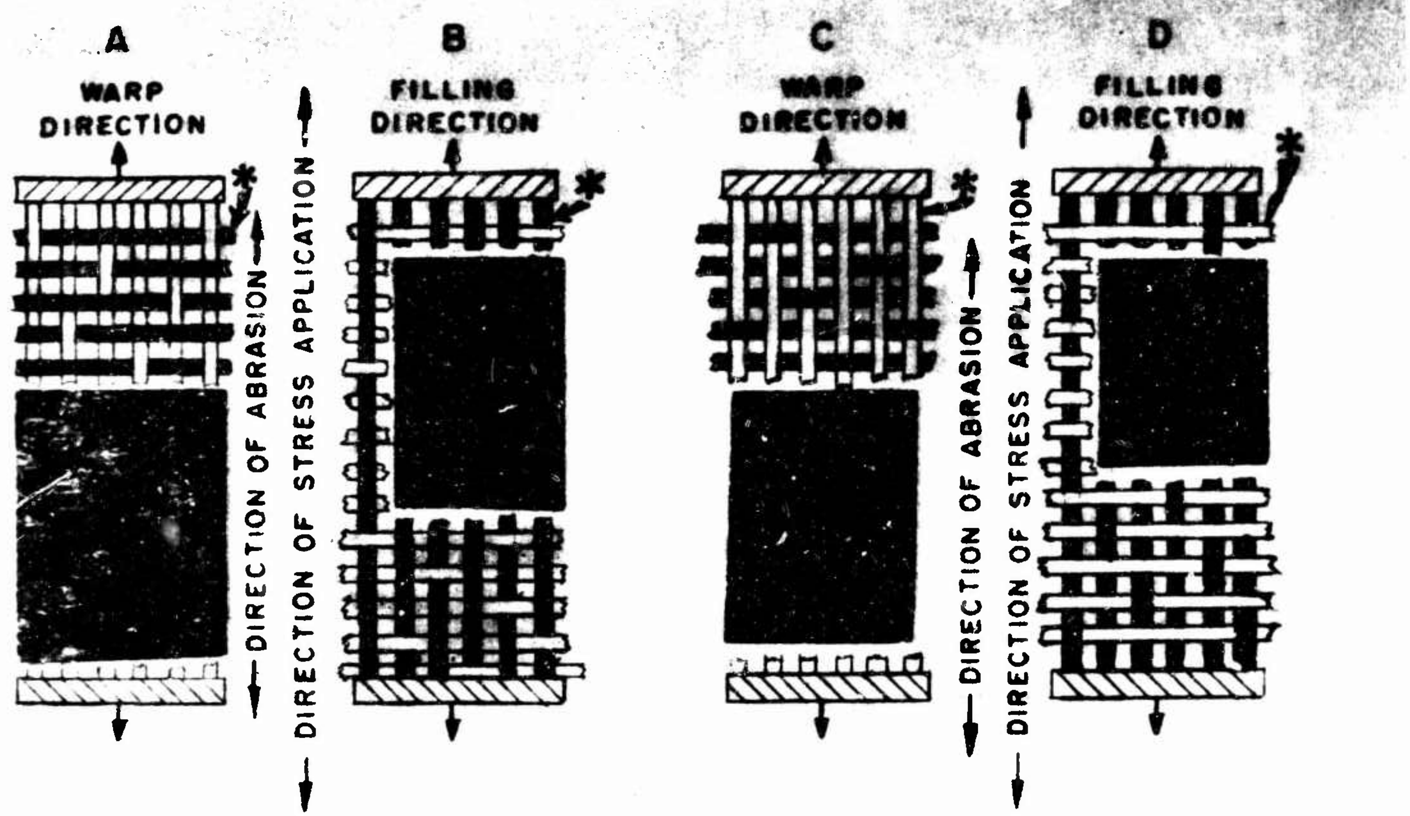
This principle is operative if the fabric is placed in the garment so that the filling yarns become the stress-bearing system. Here, maximum wear resistance would result if the sateen were worn with the face (predominantly warp side) to the outside of the garment. The four possible positions are illustrated in Figure 10. Positions A and D provide the maximum resistance to wear while positions B and C provide the least resistance. The magnitude of the differences usually obtained for each of these positions is shown in Table III for four different sateen fabrics.

TABLE III

NUMBER OF CYCLES REQUIRED TO RUPTURE FOUR DIFFERENT SATEENS, ABRADED ON FACE AND BACK IN WARP AND FILLING DIRECTIONS

		BACK (Filling Flush Side to Abradant)	
Fabric No.	Position A (Warp Direction Abrasion)	Position B (Filling Direction Abrasion)	Difference
1	890	630	260
2	1530	930	600
3	2160	1200	960
4	970	670	300
		FACE (Warp Flush Side to Abradant)	
	Position C (Warp Direction Abrasion)	Position D (Filling Direction Abrasion)	Difference
1	530	810	280
2	1000	1610	610
3	1480	2220	740
4	660	910	250

This finding has led to the exclusive use of sateen weave fabrics with the filling flush side or "back" to the outside for military fatigues and cold-weather combat clothing. Significant improvement in durability has been observed in both



* ON THE BACK OF THE FABRIC THE FILLING YARNS PREDOMINATE AND ARE INDICATED BY HEAVIER LINES.

* ON THE FACE OF THE FABRIC THE WARP YARNS PREDOMINATE AND ARE INDICATED BY LIGHTER LINES.

Figure 10. Possible Orientations of Sateen Weave

accelerated wear course and field wear. For hot-weather combat clothing, preference is still given to the plain weave since it is possible to weave it thinner and lighter in weight for a given tightness than the sateen.

8. Directional Effects in the Wear of Cotton Fabrics in Laundering

The laundering process is known to produce significant wear in cotton fabrics. This wear is usually aggravated where resin treatments are applied to the fabric for wash and wear or permanent-press purposes. Directional effects play a significant role in the wear that occurs in laundering also. To evaluate this problem, simulated shirt cuffs were made from a series of cotton fabrics using 12-inch squares of material stitched together with a 301 stitch, forming an SSc2-type seam (Figure 11a and Figure 11b).

The simulated cuffs were laundered 41 times using the Army mobile laundering system and tumbler-dried after each laundering. Wear was evaluated by counting the number of breaks in yarns at the four edges of the simulated cuffs. The samples tested include the 8.5-ounce sateen and a 6-ounce cotton poplin. Resin-treated samples of each of these fabrics were included in the test also. For each fabric, there were evaluations made of breaks in warp and filling yarns at the edges of the simulated cuffs parallel to the warp yarns, and breaks in warp and filling yarns at the edges of the simulated cuffs parallel to the filling yarns.

A plot of number of broken yarns versus laundering cycles is shown in Figure 12. A number of observations are apparent. First, there is a major difference between the number of breaks in yarns in the resin-treated cottons compared with the untreated, particularly in the sateen. Second, there is the slow induction period in the curves during which the rate of yarn breakage is quite low. This is followed by a period of rapid increase in the yarn breakage which appears to be linear with the number of launderings. For the standard sateen fabric, the number of launderings was not carried far enough to reach the period of rapidly increasing yarn breakage. What is even more significant than the observations made in Figure 12 are the locations of the breaks which are presented in Table IV. In the sateens, practically all of the breaks occurred in filling yarns, while in the case of the poplins, all of the breaks occurred in warp yarns.

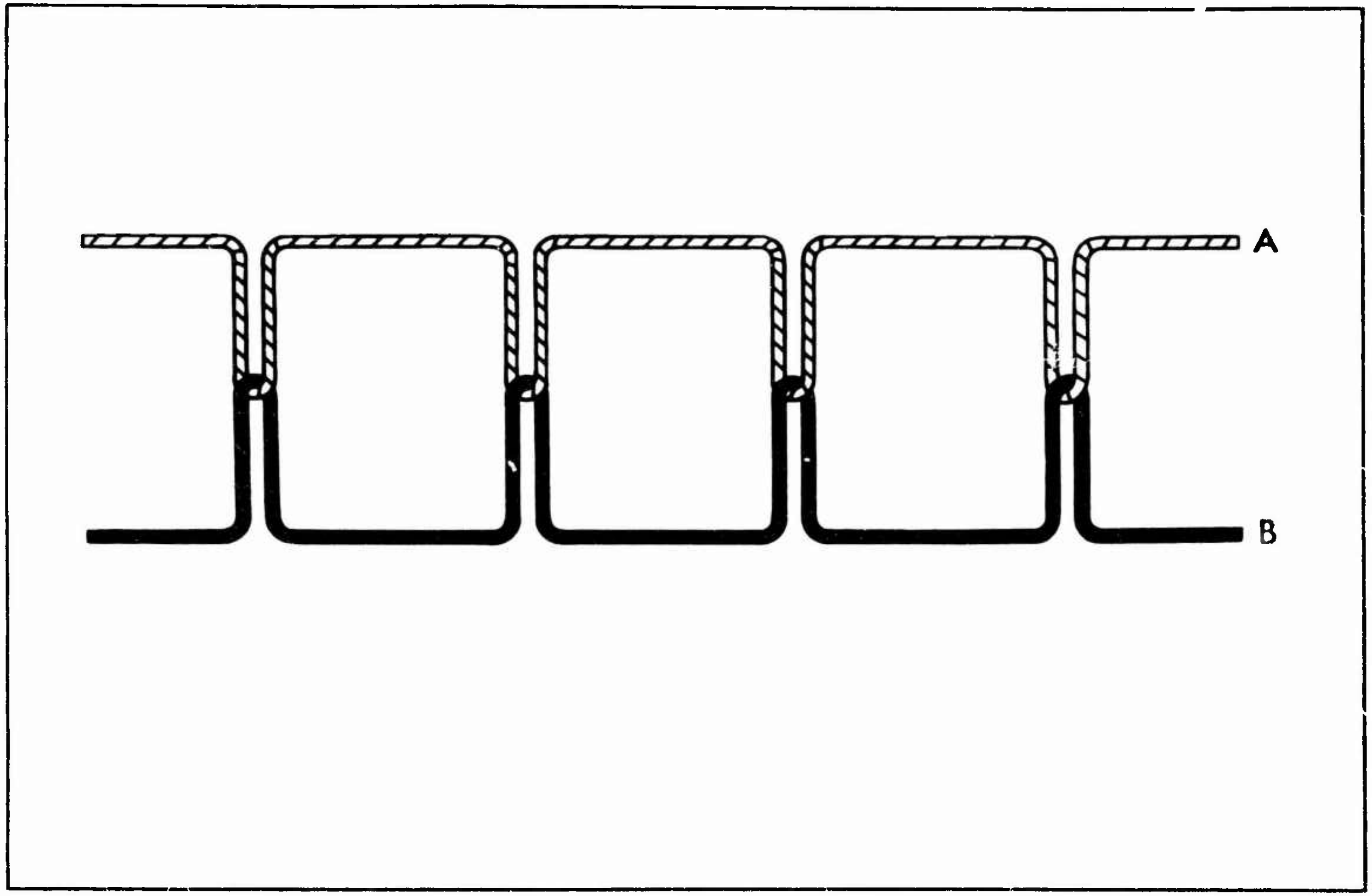


Figure 11A, Stitch Type 301

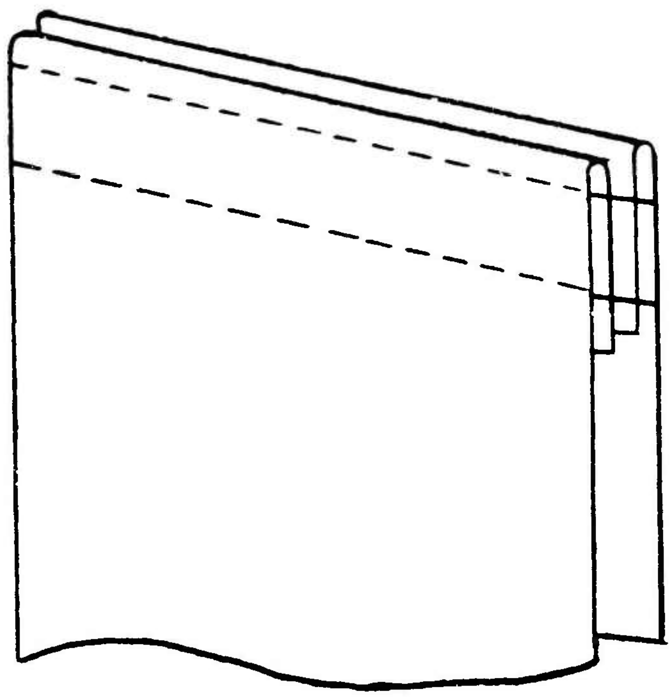


Figure 11B. Seam Type SSc2

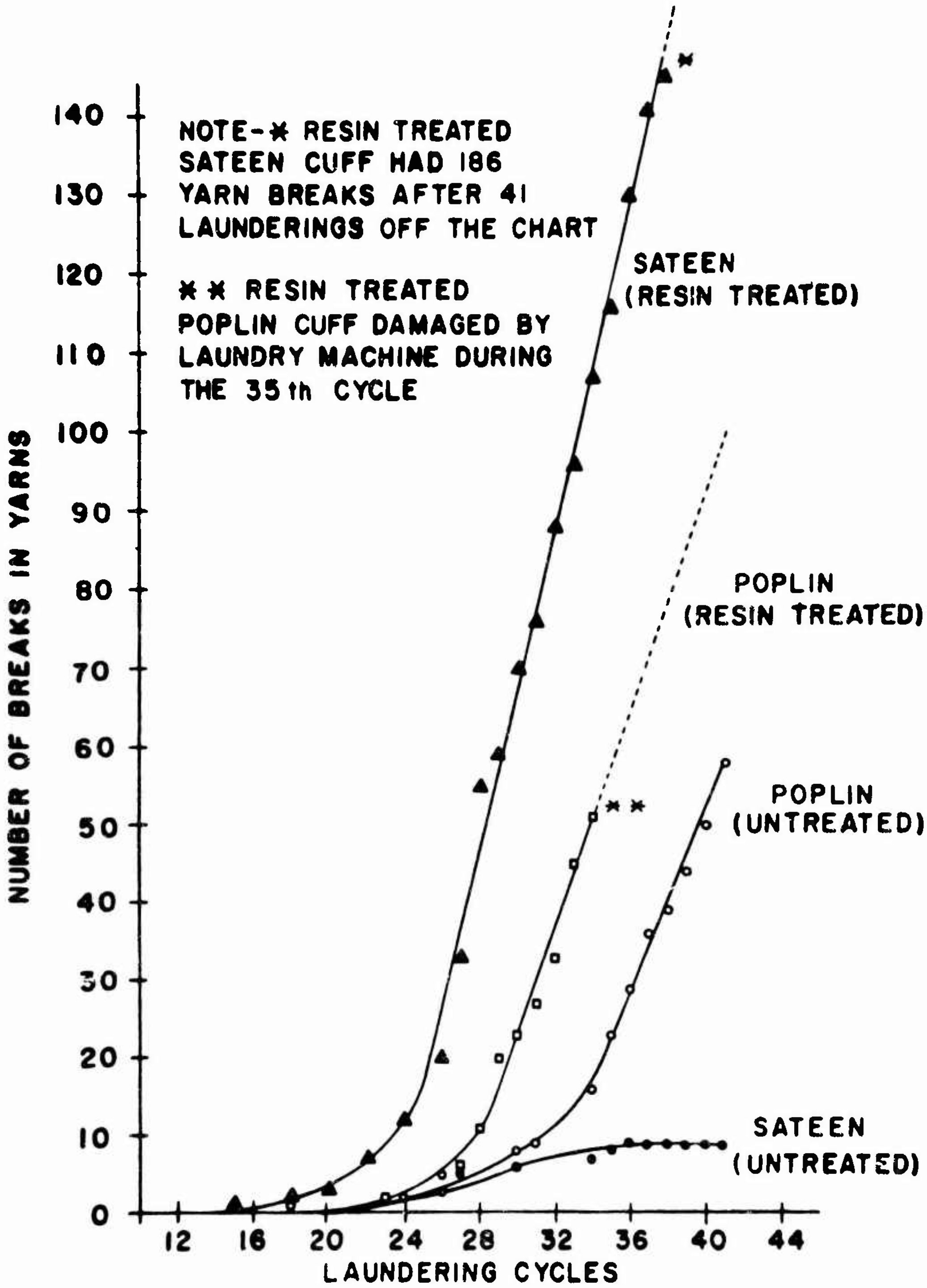


Figure 12. Breaks in Yarns vs. Laundering Cycles for Simulated Cuffs

TABLE IV

BREAKS IN YARNS IN SIMULATED CUFFS AFTER 40 LAUNDERINGS

Fabric	Breaks in Yarns	
	Warp	Filling
8.5 ounce Sateen untreated	2	7
8.5 ounce Sateen resin-treated	12	174
6.0 ounce Poplin untreated	48	0
6.0 ounce Poplin resin-treated	*	0

*50 broken yarns after 35 launderings - sample withdrawn at this point because of machine accident.

The greater number of breaks in filling yarns in the sateen can be explained on the basis of the fact that with the fabric formed into the simulated cuff with the predominantly filling side to the outside, this was the yarn system most exposed and naturally would be subjected to the greatest amount of wear stress. By the same token, the warp yarns would be protected by the filling yarn coverage and would thus be less exposed and less vulnerable to wear.

In the poplin weave, despite the fact that warp and filling yarns are both exposed, there is a significant difference in the projection of the warp yarn system above the filling yarn system because the warp yarn system practically always has the greatest amount of crimp, i.e., does the most bending during the weaving operation. Thus, the warp crowns project above the filling and become more vulnerable to wear failure.

A surprising observation was made regarding the location of the breaks in the yarns. In poplin, the breaks occurred predominantly in the warp yarns which were bent around the seam edge, the seam edge perpendicular to the warp direction of the cloth. Few breaks were observed in the warp yarns which ran parallel to the seam edge. This is an expected result, since the warp yarns were under greater strain in the position where they were perpendicular to the seam edge than where they were

parallel to the seam edge. However, in the case of the sateens, the breaks in the yarns occurred in those few filling yarns which ran parallel to and at the seam edge. This is the seam edge which is parallel to the filling direction of the cloth. Very few breaks were observed in filling yarns which bent around the other seam edge.

Additional tests are in progress on sateens and twills to evaluate directional effects as a function of face versus back orientations. It is probable that these tests will show differences as a function of orientation similar to those observed in the dry abrasion of long float weaves.

These observations suggest means of improving the wear in laundering of clothing such as overalls, fatigues, shirts, and dresses, particularly those treated for wash and wear or permanent press which are laundered frequently. For example, for both the poplin and for the sateen (worn with the face in) optimum wear in laundering should be obtained if the sleeve and trouser cuffs have the filling yarns parallel to the long dimension of the sleeve and trousers. Some of these directional arrangements can be easily achieved with slight modifications of the manufacturing process. Others are somewhat more involved - like cutting the poplin trouser leg so that the warp yarns in the cuff will be perpendicular to the long dimension of the trousers.

The interactions of the yarn systems with deteriorative environments are thus capable of being harnessed to provide desirable improvements in wear resistance. Before making directional changes, it becomes necessary to consider all of the other possible changes in fabric performance that may be associated with reversing direction in cut, make, and trim operations. Shrinkage is one significant factor that should not be overlooked, particularly in collar constructions. Normally, the greatest amount of shrinkage occurs in the warp direction of woven fabrics. If a collar is cut in the filling direction, much less shrinkage will occur in laundering than if it is cut in the warp direction. If we assume that laundering wear at the collar fold follows the same pattern as at a seam edge, then, for the sateen cut face-in, shrinkage and laundering wear could not be optimized in the same construction. However, for collars cut in the warp direction, both the sateen and the poplin should sustain less laundering wear at the collar fold.

9. Conclusions

The differences observed in the normal and laundering wear of cotton fabrics of different weave types and of different placement with face and back orientations indicate that significant improvements can be made in the serviceability of garments by taking advantage of the trends discussed. Continued study of these wear trends in the various weaves should be of particular interest to those working in the field of permanent-press cottons.

The ability to predict field wear in terms of laboratory abrasion data provides a basis for the empirical study of the influence of other structural features of textile fabrics. The Sand and Sand-Blast abraders have much to recommend them for evaluating "abrasive" type wear and should be considered for use in studies involving this wear system.

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13. ABSTRACT

Investigations on the wear of cotton fabrics were conducted by the U.S. Army Natick Laboratories. It was found that the theories of "adhesive" and "abrasive wear, originally developed for metals, when applied to textile wear problems, provide new insights into the interpretation of laboratory and field measures of wear resistance. The predominant form of wear of military clothing is of the "abrasive" type. This finding stimulated the development of two instruments: the Smith Sand-Abrader and the Sand-Blast Tester, which provide essentially the abrasive type of wear. These two instruments are described. Correlation studies indicate that the Sand-Abrader and the Sand-Blast Tester predict accelerated wear-course wear and simulated combat-wear with a reasonable degree of precision.

Early studies made by the Army on the influence of garment fabric weave and weave orientation both in field and laboratory wear were extended to determine their influence of the wear that occurs in laundering. With the increased use of resin treatments to produce desired functional properties in military fabrics, this type of wear has become more important because of the sensitivity of resin-treated fabrics to laundering damage. It was found that the location and rate of edge wear in seams is a function of weave type and fabric orientation. In poplins, failure occurs predominantly in those warp yarns bent around the seam edge which is perpendicular to the warp direction of the fabric. In sateens, made up with the filling-flush side of the fabric to the outside of the seam, failure occurs predominantly in the filling yarns at the seam edge parallel to the filling direction of the cloth. The magnitude of the differences observed are such as to suggest means of significantly reducing edge wear

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	ROLE	WT	ROLE	WT	ROLE	WT
Tests	8					
Test equipment	8					
Adhesion tests	8					
Abrasion tests	8					
Abrasion testers	8					
Cotton fabrics	9,7					
Military clothing	4					
Adhesion	6					
Abrasion	6					
Warp face	6					
Filling face	6					
Resin finishes	6					
Laundering	6					
Orientation	6					
Warp ends	6					
Filling yarns	6					
Edge wear	7					
Wear	7					

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in military garments by correct positioning of the fabric in seam structures.